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SPOTTED WILT OF WHITE, YELLOW, AND PINK CALLAS[1]

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SPOTTED WILT is a destructive virus disease of widespread occurrence in field plantings of the white calla, *Zantedeschia aethiopica* Spreng., the yellow calla, *Z. elliottiana* Engler, and the pink calla, *Z. rehmannii* Engler, in the northern end of the San Francisco Peninsula and in the Monterey Bay region of California. Because of its economic importance, field and greenhouse studies have been in progress, intermittently, for more than a decade. Discussed in this paper are the symptoms of spotted wilt on each of the three calla species, artificial transmission of the disease in the greenhouse, perpetuation of the virus in vegetative organs, and suggestions for control.

REVIEW OF LITERATURE

The first reports on the occurrence of spotted wilt on a monocotyledonous host were published in Great Britain and the United States. Ogilvie (1935)[4] and Ainsworth (1935 *a*, *b*) recorded the disease on white calla in Great Britain while Gardner and Whipple (1934) briefly mentioned its presence in California.

Ainsworth (1935 *a*) described the symptoms of the disease on leaves, flower stalks, and buds. In greenhouses, spotted wilt was spread by the onion thrips, *Thrips tabaci,* the calla flowers being favorite breeding areas of the insect. Ainsworth recommended removal and destruction of infected plants, regular fumigation with nicotine, and using only healthy stock for propagating purposes.

K. M. Smith (1935, 1937, 1945, 1947) also described the symptoms of spotted wilt on white calla, in close agreement with the work of Ainsworth (1935 *a*). For control of the disease he suggested nicotine fumigation in the greenhouse, removal and destruction of diseased plants, dusting of the plants with powdered naphthalene as a further means of checking thrips, and propagating only with seed and vegetative organs from healthy plants.

The spotted wilt virus was transmitted artificially in greenhouse tests from infected white calla to healthy tomato plants (Gardner, Tompkins, and Whipple, 1935).

Zantedeschia mosaic was reported by Edson and Wood (1936). Probably

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[4] See "Literature Cited" for citations, referred to in the text by author and date.

they were referring to spotted wilt, since there is as yet no known mosaic disease of white calla in the United States.

Noble, et al. (1937) observed natural infection of white calla by the spotted wilt virus in New South Wales, Australia.

Further reports on the occurrence of the disease in the United States were given by Nance (1939), R. E. Smith (1940), Altstatt (1942), McWhorter (1942), Milbrath (1942), Creager (1943), Kirby (1943), and Forsberg (1946).

Reporting on the host range and distribution of spotted wilt, or kromnek, in South Africa, Miss Hean (1940) listed *Zantedeschia* sp. as a host of the virus.

Infection of white calla by the spotted wilt virus has also been reported from the Netherlands (Noordam, 1943), from Belgium (Roland, 1947), and from Sweden (Lihnell, 1948).

In 1942, Selman (1945) potted one infected and one healthy Arum rhizome of flowering size. In 1943, no symptoms were visible on the infected plant. Both plants were then dug. The two large rhizomes and the offsets of each were repotted and placed in the same greenhouse. After three years, the healthy plants from healthy rhizomes continued healthy. Offsets removed from the large diseased rhizome showed no signs of disease after five months. Observations indicate that frequently growers obtain normal blooms on infected plants. Selman recommended propagating only from healthy stock.

In California, the onion thrips, *Thrips tabaci* Lind., and the flower thrips, *Frankliniella occidentalis* (Perg.) and *F. moultoni* (Hood), are known vectors of the spotted wilt virus (Bailey, 1938).

MATERIALS AND METHODS

Seeds of white, yellow, and pink callas, previously dusted with Spergon (tetrachloro-parabenzoquinone) to prevent seedling diseases, were planted in flats of autoclaved soil. Later, individual seedlings were transplanted in 5-inch pots of autoclaved soil.

Mechanical Inoculation

For inoculum, naturally infected, white calla plants (variety Godfrey) were dug in the field at Colma, as needed, and potted at Berkeley. Young leaves were crushed in a sterile mortar lined with cheesecloth. Since the viscous extract derived from calla leaves cannot be separated readily from the pulp, an improvised swab was made by twisting the cheesecloth as tightly as possible and applying pressure, at intervals, to force some juice to the surface. The leaves of seedling callas were dusted with carborundum (Rawlins and Tompkins, 1936) and inoculated by gently rubbing the upper surface with the cheesecloth swab. The leaves of inoculated plants were washed with tap water to remove the virus residue. Healthy tomato, pepper, lettuce, and China aster plants were mechanically inoculated with juice from the inoculated calla seedlings in tests for recovery of the virus. All inoculations were made in a cool greenhouse (13° to 19° C.) which was fumigated with nicotine dust at weekly intervals for insect control.

The materials and methods used in studies on perpetuation of the virus in vegetative organs are fully described elsewhere in this paper.

SYMPTOMS OF THE DISEASE

Symptoms of spotted wilt occur on the petioles, leaves, peduncles, and spathes of infected white, yellow, and pink calla plants. Although the expression of symptoms on each of the three species is similar, there are some differences which can best be discussed separately.

On White Calla

Leaves and petioles: Early in September when new growth commences in white calla fields (either new plantings or those held dormant during the summer months), the young, furled leaves and their petioles, arising from infected rhizomes, always show marked symptoms of the disease as they emerge from the soil (plate 1, *A* to *G*). In the furled condition, which exposes only the under side of the leaves, they may be slender or robust, upright or bent and distorted, and of normal height or stunted. On or between the veins and midribs are delicate to coarse, chlorotic to pale-white streaks or blotches which, alternating with bands of normal, dark green tissue, ascend spirally from the base to the tip of the leaves. Similar symptoms occur on the petioles. Sometimes the symptoms consist entirely of few to many, small to large, chlorotic to pale-white, circular lesions, scattered indiscriminately on the unfurled leaves and petioles. It is not uncommon to find a combination of symptoms, expressed in mild to severe form. If the white calla plant is severely infected, as indicated by its stunted condition, the leaves may unfurl in part or not at all. Sometimes the leaves remain furled throughout the season or until the plant becomes dormant. Infected plants at this stage of growth are distinctly chlorotic and may be much reduced in size. In general appearance they are in marked contrast to apparently healthy specimens in the same field (plate 1, *H*).

On less severely infected white calla plants, the leaves gradually unfold, displaying in full view, on both leaf surfaces, the conspicuous symptoms which characterize this disease. They consist of fine to coarse, chlorotic to pale-white streaks or blotches (plate 2, *A* to *E*) which alternate with dark green bands between the veins; of few to many, chlorotic to pale-white, circular lesions (plate 3); or a combination of both types (plate 4, *A* to *E*), scattered indiscriminately on and between the veins of the leaves and on the petioles, in marked contrast to healthy leaves (plate 2, *F* and plate 4, *F*). Generally the entire upper and lower leaf surfaces are involved, but occasionally symptoms are restricted to the base, the center, or the tip. Leaves of infected plants may retain their normal, flat form, but are usually wrinkled and distorted. Symptoms are equally prominent on both leaf surfaces. Sometimes, as mentioned above, leaves unfurl only part way, so that only a restricted area of the leaf blade is visible. The virus has a notable tendency to cause unequal or dissimilar tissue development on opposite sides of the midrib (plate 5, *A*, *B*).

With severe infection, all leaves and petioles of diseased plants show conspicuous symptoms. On less severely infected plants which have managed to make moderate or almost normal growth, some young and old leaves, devoid of symptoms and apparently normal, will be found throughout the

season. Infected plants in a given population show considerable variation in symptoms. Variation also exists on leaves of single, infected plants.

Spathes and peduncles: These parts of infected white calla flowers generally show marked symptoms of the disease, the intensity depending upon severity of infection. On flowers, from unopened buds to fully expanded spathes, and on peduncles, yellowish-green to pale-white, narrow to wide, short to long streaks or blotches appear singly or in chainlike formation, on or between and parallel to the veins (plate 6, *A* to *E*). A second type of symptom, equally common, consists of few to many, small to large, circular to irregular shaped, yellowish-green to pale-white lesions, similarly distributed (plate 6, *A* to *E*). Sometimes streaks and lesions occur in combination (plate 6, *A* to *E*). The furled spathes may be straight or deformed, thin or thick, and stunted or of normal height (plate 5, *C, D, E, F*). If infection is mild, infected flower buds may open to expose the spathe in its entirety. In severely infected plants the spathes open in part or not at all. When flower buds fail to open, their predominant color is greenish-white to yellowish-white rather than the normal creamy-white. Recurvature, or wavelike distortion, of part or all of the edge of the spathe occurs on partly or fully opened spathes (plate 5, *C, D, E, F*). Also, the outer or exposed surface of the flower buds (the lower surface of the spathe) and the peduncles are smooth to rough and warty, the raised areas, similar to those produced on tomato fruits by the virus, being dark green in color. Infected flowers, even though borne on long peduncles, cannot be marketed, and are in marked contrast to healthy specimens (plate 6, *F*). When flowers are held for seed production the spathes gradually turn green, and on infected flowers this tends to accentuate the symptoms which persist until the spadices mature.

During cool, foggy weather, symptoms of the disease may be found on the commercial varieties of white calla throughout the year. In any field, infected specimens are discernible from the distance because they are lighter in color, compared with healthy plants, and slightly to severely stunted and distorted. No two infected plants show identical symptoms, owing to the wide variety induced by the virus. Severely infected white calla plants may be killed by this disease.

It is impossible to detect virus-infected rhizomes after harvest by visual examination, because apparently their shape remains unaltered. Even size of rhizomes appears to be an unreliable criterion.

On Yellow Calla

Symptoms of the disease on yellow calla are essentially like those occurring on white calla, and are to be seen in the field from April when new growth begins until the foliage matures in August or September. It should be noted that healthy yellow calla leaves have small to large, transparent, white streaks and circular to oval white spots which are distributed at random between and parallel to the veins (plate 7, *C*). Such markings are lacking in healthy leaves of white and pink calla.

Leaves and petioles: Chlorotic to pale-white, small to large streaks and lesions, either alone or in combination (plate 7, *A, B* and plate 8, *A, B, C*) occur on infected yellow calla leaves and petioles. They are distributed at

random on and between the veins and on the midrib of the leaves and are equally conspicuous on the petioles. The streaks are usually dark green and may coalesce to form long, irregular-shaped bands with enclosed green islands. Later, these streaks may become necrotic, imparting a light-brown color to the leaves (plate 9, *A, B, C, D*). Lesions may be of different types. Some are chlorotic to pale-white in their entirety or may show lighter to dark centers; some are dark green with light centers. Again, lesions may consist of light to dark-green, concentric rings, the edges of which are sometimes necrotic (plate 8, *D* and plate 9, *C, D*). Partially formed, necrotic lesions are not uncommon. The lesion or ring pattern appears to be of more common occurrence in yellow than in white callas. It is largely responsible for the interveinal, chlorotic condition, whereas the streaks impart a darker-than-normal green color to the leaves. Wrinkling of the tissues on and between the veins produces a wavy leaf and is of common occurrence. Part or all of the margin of diseased leaves may roll upward or downward. Occasionally, leaves are malformed, resulting in a "fern-leaf" or "shoestring" condition.

Spathes: The petioles, peduncles, and flowers of yellow calla usually show much more severe symptoms than those of white calla (plate 10, *A, B, C* and plate 11, *A* to *D*). The normal golden-yellow color of the spathe undergoes bleaching which accentuates the ring pattern and renders the flowers unsaleable. Healthy yellow calla spathes are in marked contrast to diseased specimens (plate 10, *D*).

When infected yellow calla corms are planted in pots for greenhouse forcing, conspicuous symptoms develop on the new plants, often so severe that the plants must be discarded.

On Pink Calla

Pink calla appears to be highly susceptible to spotted-wilt infection, as indicated by the severity of symptoms. Leaves may show coarse, chlorotic to pale-white streaks (plate 13, *A, B, C*), an abundance of small, chlorotic to pale-white lesions (plate 12, *A, B, C*), or a combination of both, on or between the veins and the midrib. Infected leaves are in marked contrast to healthy specimens (plate 12, *D* and plate 13, *E*). Gradually these symptoms change to extreme general chlorosis. Many lesions and streaks are arranged in chain formation and may become entirely necrotic, or necrotic around the edges only (plate 13, *D*). Sometimes the necrotic lesions coalesce to form necrotic streaks on and between the veins and on the midrib. The petioles and peduncles are similarly affected. The normal pink color of the spathe is bleached to a creamy-white. Usually numerous, small to large, flat or raised, chlorotic to pale-white or necrotic lesions dot the surface of the spathe (plate 14), rendering the flowers unsaleable. While stunting of the plants is common, it is less severe than on white and yellow callas.

As with potted yellow callas, symptoms of the disease on potted pink callas are severe.

TRANSMISSION OF THE DISEASE

Inoculation of Seedlings

The literature on spotted wilt reveals no records of inoculations of seedling calla plants. It semed desirable, therefore, to conduct such routine tests in conjunction with the other phases of investigation reported in this paper.

In 1946, 50 seedlings each of the three species of calla were mechanically inoculated in the greenhouse, while the same number of noninoculated plants served as controls. Of the white calla seedlings, 41 became infected in 15 to 29 days; of the yellow calla seedlings, 45 showed symptoms of the disease in 10 to 25 days; and of the pink calla seedlings, 38 were diseased in 14 to 34 days. The symptoms shown by artificially infected plants were comparable to those observed in the field on naturally infected callas. The virus from each infected calla was recovered on one or more test plants. Expressed juice from inoculated but symptomless calla plants failed to infect test plants when transferred by mechanical inoculation. All control plants remained healthy.

Transmission by Seed

Apparently the spotted wilt virus is not transmitted through calla seeds. Mature spadices were collected from naturally infected calla plants and later crushed in water in order to remove the seeds from the pulp. After drying, 3,000 white, 5,000 yellow, and 5,000 pink calla seeds, previously dusted with Spergon, were sown in flats of autoclaved soil in the greenhouse. Germination was approximately 90 per cent, and all seedlings developed healthy foliage.

Examination of numerous commercial seedbeds, in fields and lathhouses, lends support to the negative evidence obtained in these experimental tests. Although thousands of seedling calla plants have been checked several times during each of ten consecutive seasons, no diseased specimens have been located. It is estimated that observations were made on at least 200,000 white calla, 2,000,000 yellow calla, and 500,000 pink calla seedlings.

PERPETUATION OF THE VIRUS IN RHIZOMES AND CORMS

White Calla

In the autumn of 1944, 90 naturally infected white calla (variety Godfrey) clumps were staked individually in a commercial planting at Colma. All showed severe infection as evidenced by their stunted condition and malformed and spotted leaves and flowers. Later, the 90 clumps were dug by hand, and the offsets or young rhizomes were separated from the old rhizomes. Each group of offsets was designated by a number corresponding to that assigned the old rhizomes from which they had been detached. The old rhizomes were then planted individually in 7-inch pots. The offsets were planted in 6-inch pots, usually with 3 or 4 offsets per pot. The number of offsets from a single old rhizome ranged from 1 to 32, with an average of 11 offsets per plant. All pots were placed on a bench out of doors at Berkeley and given frequent watering and cultivation.

In May and June, 1945, records were taken on the condition of the plants. All plants arising directly from the 90 old rhizomes showed severe infection,

as indicated by foliage symptoms. Of the 1,043 plants arising from the same number of offsets, 99 plants showed no foliage symptoms but failed to make normal growth. Of the remaining 944 plants, all were infected, or 91.7 per cent of the total number of offsets planted.

Masking of symptoms: Not all of the offsets separated originally from each old rhizome developed symptoms of the disease. Although 42 of the old rhizomes and all of their offsets showed severe foliage symptoms after replanting, a total of 99 plants arising from the same number of offsets taken from 48 of the original clumps were not visibly infected. The number of offsets failing to show symptoms of the disease ranged from one to seven per clump. Subsequent mechanical inoculation of tomato, tobacco, pepper, and China-aster potted plants in the greenhouse with juice extracted from the leaves of these symptomless calla plants gave infection. The conclusion was drawn that, in spite of lack of any symptoms, the virus was nevertheless distributed systemically throughout these plants. The reason for masking of symptoms at Berkeley is not known.

Other Varieties

Essentially the same tests were made on naturally infected yellow and pink calla corms but on a much more limited scale. In 1944, 50 infected yellow calla and 50 infected pink calla plants, previously staked, were dug at Santa Cruz. There were 129 yellow calla, and 206 pink calla offsets respectively. Three months after potting the 100 old yellow and pink calla corms and all their offsets in the greenhouse at Berkeley, all new plants arising directly therefrom showed typical foliage symptoms of spotted wilt.

Other species and varieties of *Zantedeschia* may be expected to react similarly. This is supported by tests with a few corms of black calla, *Arum palaestinum* Boiss., spotted calla, *Z. albo-maculata* Baill, and black-throated calla, *Z. melanoleuca* Engler, in which potted plants arising from offsets taken from naturally infected corms developed typical symptoms of the disease, as did plants from the old corms.

Conclusion

These tests indicate that the spotted wilt virus is systemic in and perpetuated by means of the rhizomes and corms of white, yellow, and pink callas.

CONTROL OF THE DISEASE

The large white calla varieties are propagated commercially by means of rhizomes and seldom from seed. It is therefore most probable that control of spotted wilt to any degree in presently planted areas will depend upon sanitary measures, i.e., roguing of infected plants and their destruction by burning.

To test the effectiveness of sanitary measures, five adjoining fields of newly planted white callas at Colma, totaling five acres, were selected for experimentation in 1944. The average incidence of disease in these fields exceeded 30 per cent, as shown by counts based upon foliar symptoms. In an adjoining sixth field of approximately one acre, most of the plants were infected. The owner was persuaded to dig and to dispose of this crop at once. Other white

calla plantings were located at least one-half mile distant from the experimental area. In general, optimum environmental conditions prevailed for the expression of symptoms.

At biweekly intervals during the growing season of 1944, 1945, and 1946, which extends from September to June, all plants in the five fields were inspected for spotted wilt. Infected plants were marked with wooden stakes to facilitate their removal. Usually they were dug on the day of inspection, care being taken to remove all rhizomes attached to infected plants. All plant refuse was piled and burned. More diseased plants were removed from each field during the early part of the first season than at any other time.

As the season progressed, additional plants, which had previously appeared healthy, suddenly developed pronounced symptoms and were removed. Late-symptom development may have resulted either from new infections induced by flights of the insect vectors from other infected hosts in the area or from other unknown factors. Infected white calla plants continued to appear at intervals, but in small numbers, from the middle to the end of the first season and during the succeeding two seasons.

In general, infected callas were scattered throughout the plantings and seldom were localized in rows or spots. The spaces in the rows caused by removal of infected plants were soon filled, as the season progressed, by increased growth of the healthy plants on either side, so that roguing did not mar the general appearance of the fields.

Roguing was conducted during three successive seasons. The incidence of the disease, based on leaf appearance, was reduced from 30 per cent at the beginning of the first season to less than 5 per cent at the end of the third season. In ordinary white calla plantings in the same area, the percentage of infected flowers which could not be marketed was usually high. Roguing thus had a marked effect on flower production in the experimental area. Flowers developed normally and only a few were infected. It is unlikely, however, that the spotted wilt virus can ever be entirely eliminated from any of the existing white calla stocks in the Colma area, because of contamination which cannot be controlled.

It had been planned to save all of the white calla rhizomes, large and small, which were harvested in the five experimental fields at the end of the third season, to serve as new-foundation planting stock. However, this plan was only partially realized. Due to favorable market prices, all rhizomes of flowering size were sold for winter forcing of flowers in eastern greenhouses. Only the small rhizomes remained for planting stock. However, they proved definitely superior to any of the ordinary, commercial, nonrogued white calla planting stocks in the Colma area. This was apparent during the fourth season, when fields planted with small rhizomes from the previously rogued plots were inspected. There was only a trace of the disease.

No roguing tests were conducted in fields of yellow and pink callas.

DISCUSSION

White Callas

The field culture of white callas for cut flowers and rhizomes is concentrated in the northern end of San Mateo County, with its favorable maritime climate and sandy soil. Rhizomes are usually harvested two or three years after planting. They are cleaned, graded, and all of flowering size are shipped immediately to eastern greenhouses for winter forcing of flowers. All commercial stocks of rhizomes grown in this part of California carry the spotted wilt virus, and some are highly infected. This applies also to the smaller rhizomes, or planting stocks, which are replanted on new land. Since, as these studies have shown, the virus infects all young rhizomes of infected plants, its dissemination may be rapid over a wide area. Unfortunately, there are no known virus-free stocks of white calla rhizomes in California. Growers are able to sell their present stocks of flowering-size rhizomes in eastern markets primarily because no better stocks are avaliable. If the proportion of defective flowers produced on infected white calla plants grown in the field at Colma is any criterion, then eastern growers who purchase the presently infected stocks must sustain comparable losses.

Available land for white calla culture in the Colma area is expensive, restricted in acreage, and is rapidly being absorbed for subdivision and home construction. There is little or no opportunity to isolate any plantings, either of rogued stocks or of those which might be started from seed. Also, since but few growers are interested in calla improvement, the prevalence of spotted wilt may continue on a high level.

It is suggested that new, healthy, white calla planting stocks, almost or entirely free from the spotted wilt virus, could be developed by locating seedbeds in and confining all propagation to the isolated valleys which are to be found near the Pacific Ocean. Since the spotted wilt virus is apparently not seed-borne, such stocks, intended primarily for local field and greenhouse culture, would command premium prices.

Yellow and Pink Callas

Since its recognition some years ago on field-grown yellow and pink calla plants in the Monterey Bay region, spotted wilt has been found to be widely distributed, and is one of the two principal diseases affecting these crops. The percentage of infection is usually very high, probably because of the wide range of naturally infected, annual and perennial ornamentals which are cultivated in the same area. They serve as excellent reservoirs of infection, making the practice of roguing of doubtful value.

With recent exception, the culture of yellow and pink callas for cut flowers and corms has been confined largely to the Monterey Bay region. These crops are dug each fall, cleaned, graded, and the flowering-size corms shipped East for commercial greenhouse forcing in beds or pots, and garden culture. Many complaints of calla failures emanating from eastern sources can be attributed, in part at least, to spotted wilt (Kirby, 1943, p. 27). Lately, new plantings from seed have been established in isolated valleys near the coast in San Mateo County where soil and climatic conditions are especially favorable for the production of yellow and pink callas for cut flowers.

It is relatively easy to maintain healthy yellow and pink calla stocks if care is taken to prohibit the introduction of other previously infected ornamentals. Also, any white calla plants near ranch houses or barns should be destroyed because they are usually infected. If spotted wilt is found at times in new plantings, prompt roguing should assure satisfactory control.

Insecticides

New insecticidal materials, such as DDT, have been made available to growers within recent years. Dusting or spraying of white, yellow, and pink calla plants and the weeds on the borders of the fields with a suitable insecticide for control of the vector would seem to be a desirable practice.

SUMMARY

Spotted wilt is a serious virus disease of white, yellow, and pink callas which are field-grown from rhizomes and corms in the coastal areas of central California.

The symptoms of the disease are essentially alike on the three calla species, with minor differences. In general, they consist of chlorotic to pale-white streaks and circular lesions, some of which may later become necrotic, distributed interveinally on the leaves.

The petioles, peduncles, and spathes are similarly affected. Leaves may also be wrinkled and distorted, and the margins may curl upward or downward. Usually, the color of infected spathes is bleached. Diseased plants, when compared with healthy specimens, are chlorotic, distorted, and stunted.

With powdered carborundum as an abrasive, the virus was transmited mechanically to healthy white, yellow, and pink calla seedlings in the greenhouse, where air temperatures ranged from 13° to 19° C. Inoculum was obtained from field-grown, infected white callas. Most of the seedlings became infected systemically in 10 to 34 days.

Greenhouse tests on seed transmission of the virus in each of the three calla species yielded negative results. This is in accordance with field observations.

Perpetuation of the virus in vegetative organs, i.e., in rhizomes or corms and their offsets, was demonstrated experimentally by pot culture of infected stock.

Roguing of white callas in moderately infected field plantings may prove beneficial, as indicated by experimental tests, but the effect is only temporary. The obstacle of natural contamination, or spread of the disease from other calla plantings and from other infected ornamental hosts in the same area, appears to be insurmountable.

Healthy stocks of calla rhizomes and corms could be propagated from seed in isolated coastal valleys, and there kept reasonably free from spotted wilt. Then, if necessary, roguing could be practiced to advantage.

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141

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Plate 1. Symptoms of spotted wilt on unfurled leaves of white calla (*Zantedeschia aethiopica*): *A*–*G*, chlorotic to pale-white streaks and lesions, with distortion; *H*, healthy leaf.

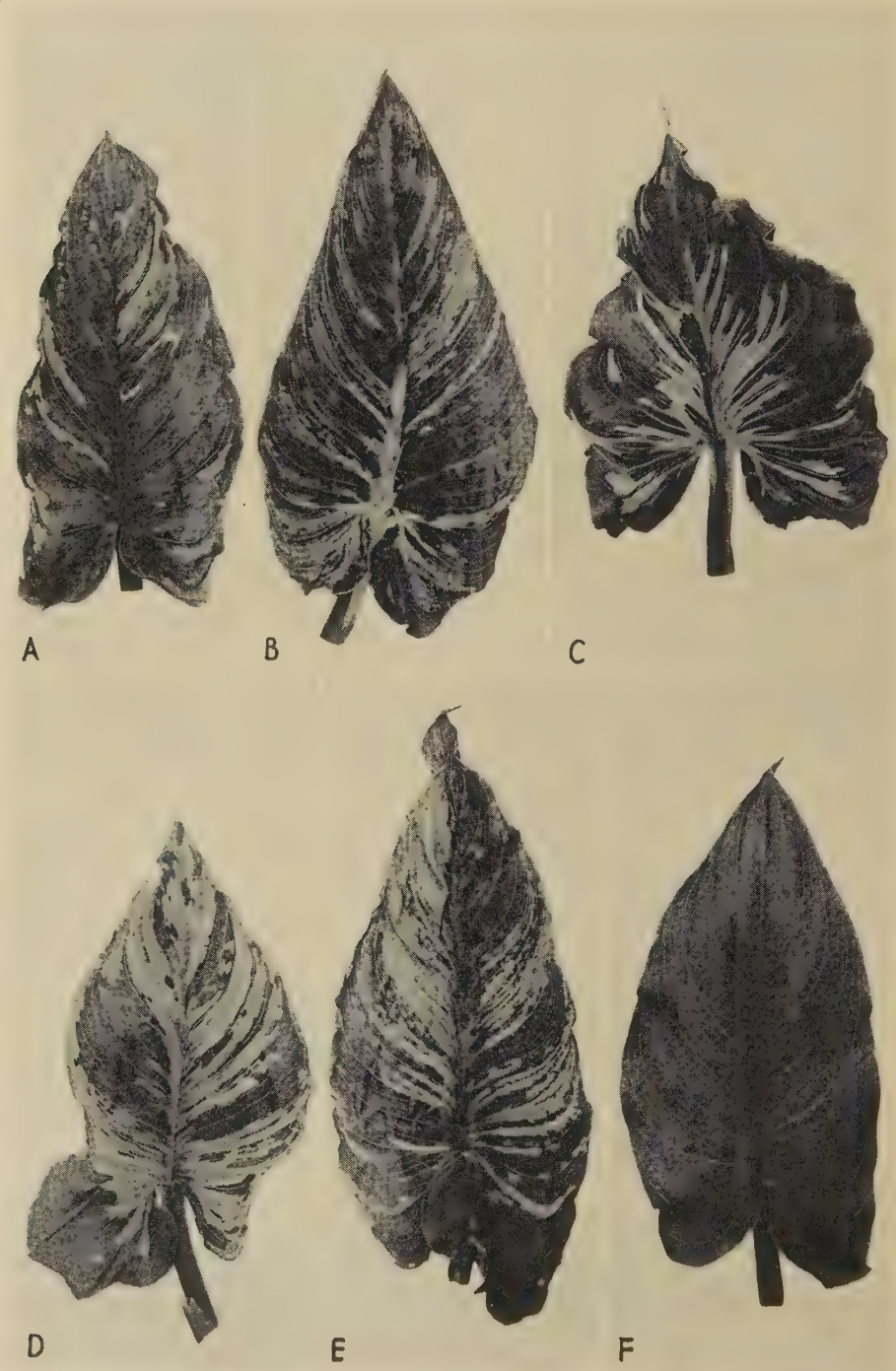

Plate 2. Symptoms of spotted wilt on leaves of white calla (*Zantedeschia aethiopica*): *A–E*, various stages of chlorotic to pale-white streaks; *F*, healthy leaf.

Plate 3. Symptoms of spotted wilt on leaves of white calla (*Zantedeschia aethiopica*): chlorotic to pale-white, circular to oval lesions.

Plate 4. Symptoms of spotted wilt on leaves of white calla (*Zantedeschia aethiopica*); *A*–*E*, showing a combination of chlorosis to pale-white streaks and lesions; *F*, healthy leaf.

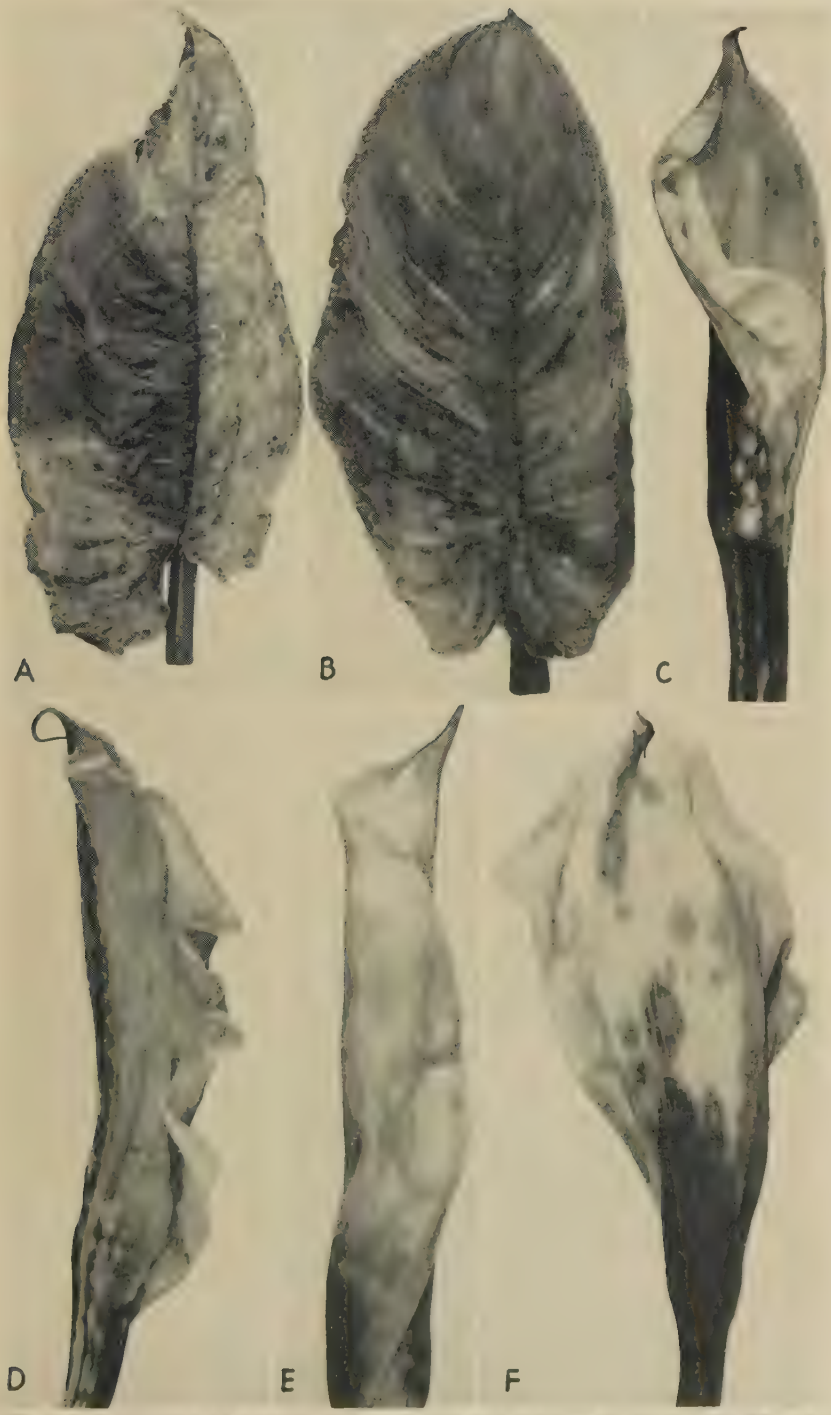

Plate 5. Symptoms of spotted wilt on leaves and spathes of white calla (*Zantedeschia aethiopica*): *A*, *B*, showing deformed, wrinkled leaves; *C*–*F*, abnormal marginal twisting and rolling of the spathe.

Plate 6. Symptoms of spotted wilt on spathes and peduncles of white calla (*Zantedeschia aethiopica*): *A–E*, small to large, chlorotic to pale-white streaks and lesions; *F*, healthy spathe.

Plate 7. Symptoms of spotted wilt on leaves of yellow calla (*Zantedeschia elliottiana*): *A*, coarse pattern of chlorotic to pale-white streaks and lesions; *B*, coarse streaks; *C*, healthy leaf, showing normal white streaks and spots.

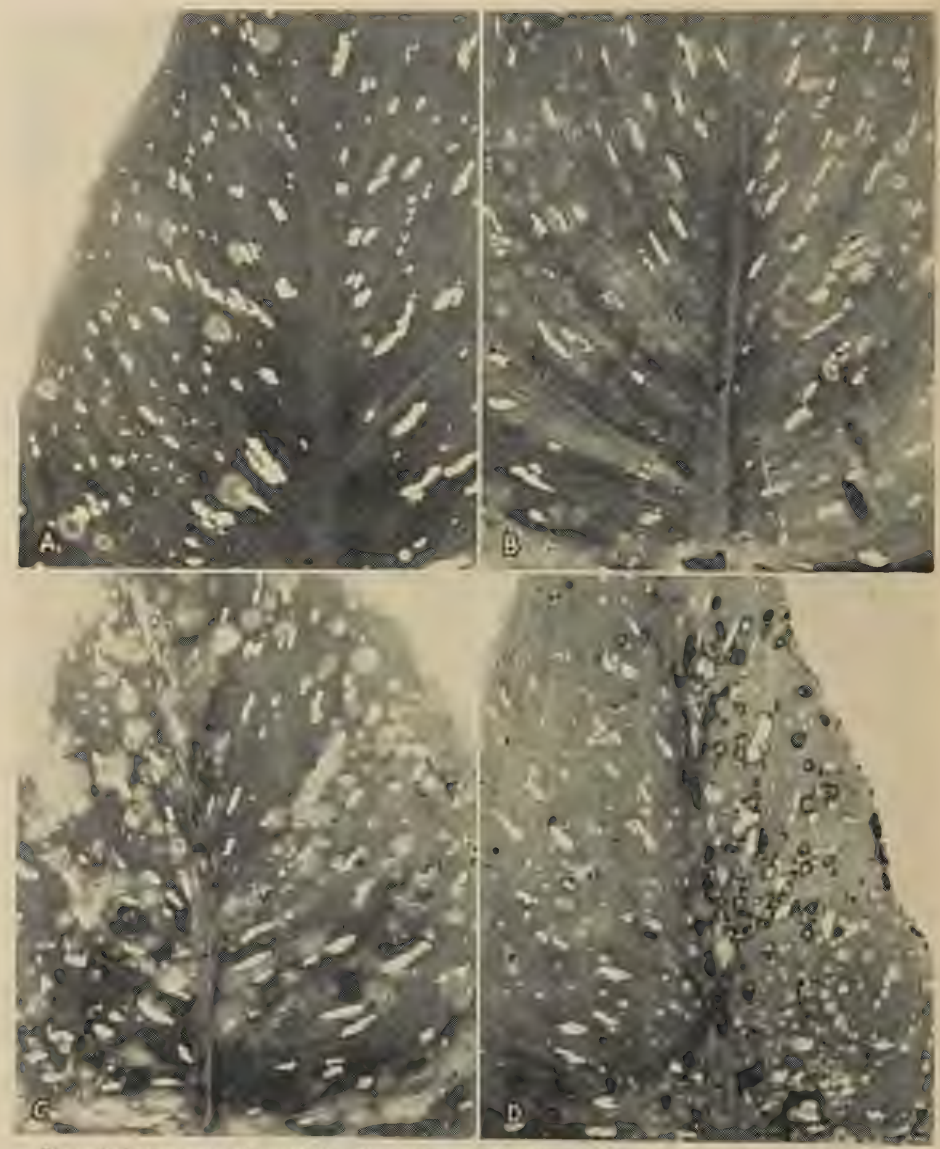

Plate 8. Symptoms of spotted wilt on leaves of yellow calla (*Zantedeschia elliottiana*): *A*, large, pale-white lesions with light- to dark-green centers; *B*, small, pale-white lesions with light- to dark-green centers; *C*, small to large, pale-white lesions, showing coalescence and a trace of marginal necrosis; *D*, small to large, pale-white lesions, showing marginal necrosis.

Plate 9. Symptoms of spotted wilt on leaves of yellow calla (*Zantedeschia elliottiana*). *A*, small to large, chlorotic to pale white lesions, some of which show concentric ring formation and marginal necrosis between the veins and on the midrib; *B*, small to large, chlorotic to pale white lesions with necrotic margins, and necrotic streaks and lesions on the midrib; *C*, chlorotic to pale white to brown (necrotic) streaks and lesions; *D*, severe necrotic streaks and lesions, showing coalescence.

Plate 10. Symptoms of spotted wilt on spathes of yellow calla (*Zantedeschia elliottiana*): *A–C*, small, chlorotic to pale-white lesions, with marginal distortion; *D*, healthy spathe.

Plate 11. Symptoms of spotted wilt on spathes of yellow calla (*Zantedeschia elliottiana*): *A*, chlorotic to pale-white streaks and lesions (mild infection); *B*, streaks and lesions (severe infection); *C*, *D*, distorted, wrinkled spathes.

Plate 12. Symptoms of spotted wilt on leaves of pink calla (*Zantedeschia rehmannii*): *A*, early stage of infection, showing small, pale-white lesions at left center and at tip of leaf; *B*, *C*, later stage, showing severe infection as indicated by abundance of lesions; *D*, healthy leaf.

Plate 13. Symptoms of spotted wilt on leaves of pink calla (*Zantedeschia rehmannii*): *A–C*, chlorotic to pale-white streaks; *D*, chlorotic to necrotic streaks and lesions; *E*, healthy leaf.

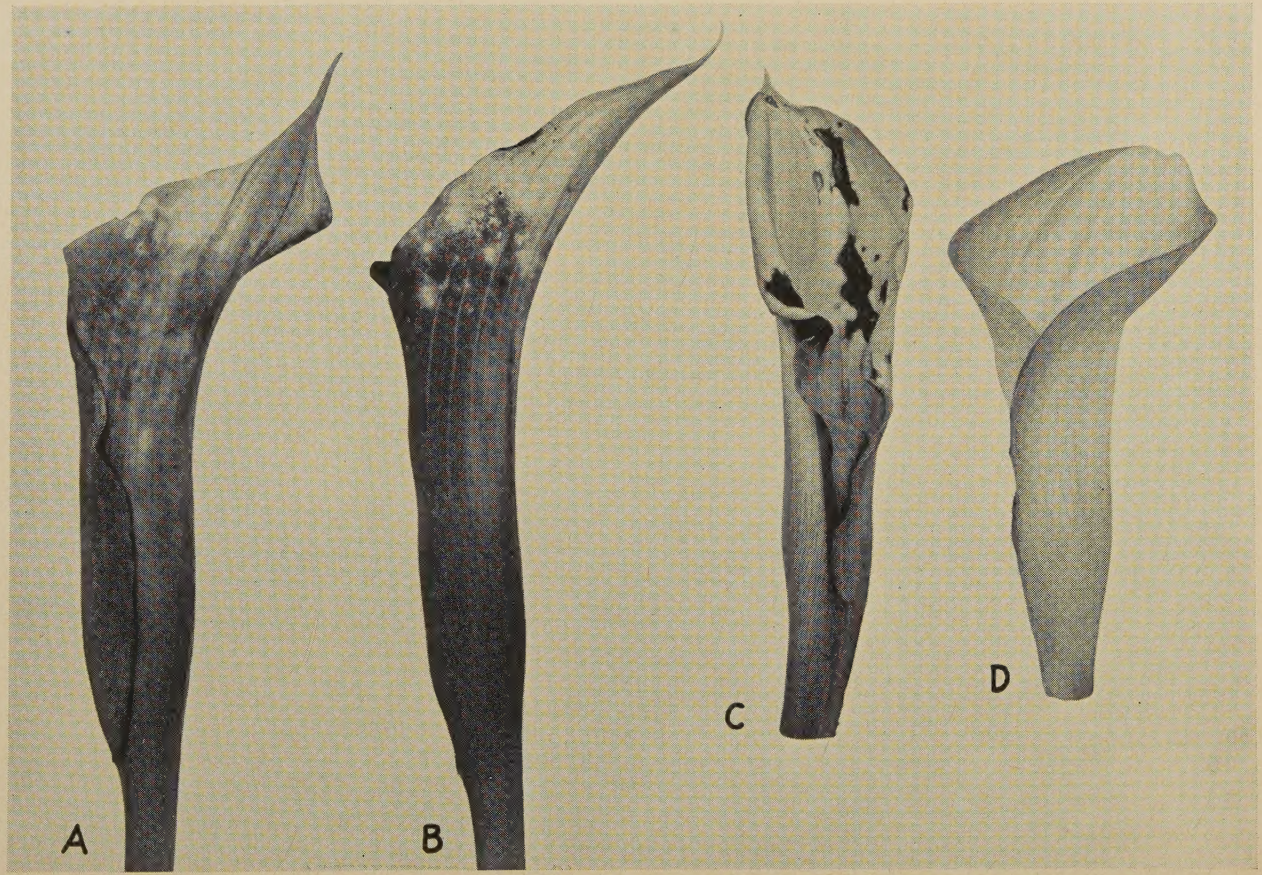

Plate 14. Symptoms of spotted wilt on spathes of pink calla (*Zantedeschia rehmannii*): *A*, *B*, infected spathes showing ring pattern; *C*, infected spathe showing necrosis; *D*, healthy spathe.